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Some Factors Affecting the Progeny Testing of Rams

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INTRODUCTION

Progeny testing in some form is an essential part of any breeding program designed for the improvement of livestock. Since the principles involved in the testing of sires have been adequately discussed by Smith and Robison (*8*), [2] Bonnier (*1*), and others, they will not be repeated in this circular.

Progeny testing has been practiced most extensively in dairy-cattle breeding and in recent years has become rather generally accepted as the best measure to use in selecting a sire. Sporadic attempts have been made to apply the method to work animals and to those used in the production of meat and fibers, but, with the exception of the swine-breeding work in Denmark, as reported by Lush (*5*), no large-scale projects have been carried out that are comparable to the work with dairy cattle.

Obstacles in the testing of sires in other than dairy cattle include the following: (1) The lack of objective measures of performance in many important characters; (2) the necessity of considering more than two characters in many cases or the impossibility of measuring adequately, with a single "yard-stick," such a character as mutton form or fleece; (3) the lack of adequate data for evaluating most of the environmental effects; and (4) the greater cost of obtaining the necessary records.

[1] The authors are indebted to D. A. Spencer, in charge of sheep-husbandry investigations in the Bureau of Animal Industry, for planning and directing the experimental work which resulted in the data analyzed, and to W. A. Denecke, J. M. Cooper, S. L. Smith, and J. A. Stoehr, of the Bureau, who collected the data at the United States Sheep Experiment Station, Dubois, Idaho.

[2] Numbers in parentheses refer to Literature Cited, p. 17.

In a practical breeding program, the cost of any method used must be more than offset by benefits resulting from more rapid progress in breeding superior animals. The ultimate aim is to have a few simple procedures, for recording merit, that are as objective as possible and suitable for making comparisons between progeny groups. Much difficult and careful work lies behind the relatively simple formula by which the dairy-cattle breeder evaluates a prospective herd sire. Similar work must inevitably precede the development of adequate methods for progeny testing of sires in other classes of livestock.

The present investigation was undertaken to determine the possibilities of progeny testing under range conditions and to study some of the factors that must be considered in evaluating rams by the progeny test. The characters selected for study were body weight, fleece weight (unscoured), and fleece length. These characters were selected both because of their importance in the sheep industry and because they can be measured easily and in definitely objective terms. The study includes the determination of the environmental effects of different years on these characters, the determination of the mean and variability of the population for each character for use as a standard or basis of comparison, an analysis of the relation of the records of the daughters to the records of their dams, and a comparison of the progeny of different rams. All these are then taken into consideration in the application of the progeny test in experimental and practical sheep breeding.

ANIMALS USED AND EXPERIMENTAL PROCEDURE

The animals used in this study included 762 Columbia, 709 Corriedale, and 764 Rambouillet ewes from the Bureau of Animal Industry's flocks at the United States Sheep Experiment Station, Dubois, Idaho. These ewes were born during the years 1925 to 1936 inclusive and, with the exception of those which appear as dams but not as offspring, were sired by 11, 17, and 17 rams, respectively, in the 3 breeds. Each of these rams had 20 or more female offspring that were retained until data on body weight, fleece weight, and fleece length were obtained at or near 1 year of age and that had dams for which, as yearlings, data on body weight, fleece weight, and fleece length were available. Offspring judged to be inferior were discarded at weaning time, in accordance with the usual practice at the station of not retaining lambs that were noticeably deficient in characteristics desired in a range flock.

Among the Corriedale and Rambouillet ewes there were 649 and 638 dam-daughter pairs, respectively, that were used in the studies involving relationships between dams and daughters. Since the results obtained for these 2 breeds were similar and were considered adequate for the present purpose, and since the Columbias are not so well established as a breed, this phase of the study was not extended to the last-mentioned group.

The data used were obtained at shearing time, when the animals were approximately 14 months old. Fleece length was measured at the middle of the side of the animal with a thin ruler by three experimental workers just prior to shearing, fleeces were weighed immediately after removal, and body weights were obtained immediately after shearing.

The sheep were handled in bands under typical range conditions. They were sheltered only at lambing time and grazed on the range from the opening of spring in March or April until they were almost snow-bound in December or January. From December or January to March or April they were fed in the irrigated valleys on alfalfa hay. From about 1 month before lambing until good grazing was available on the range, ewes were fed a limited quantity of a grain supplement in addition to the hay. Ewes that lambed at the lambing shed before good grazing was available were given some additional feed.

In the spring and fall the ewes and lambs grazed on range of the sagebrush type near Dubois, Idaho. During the summer they were in the Targhee National Forest, about 40 or 50 miles west of Yellowstone National Park, where a good supply of palatable forage was usually available.

YEARLY VARIATIONS OF THE FEMALE PROGENY IN BODY WEIGHT, FLEECE WEIGHT, AND FLEECE LENGTH

In a consideration of the relative merit of the progeny of different rams when all offspring being compared are not born in the same year, the first problem to be studied is the effect of different years on the characters for which comparisons are being made. If differences between years are of no importance they may be disregarded in continuing the analysis, but if significant yearly differences are found they must be considered in carrying out each succeeding step of the problem.

The data for each breed during each year of the study are given in table 1. To eliminate any differences in the progeny that might be due to differences in dams, adjustments for the covariance between dams and daughters in the Corriedale and Rambouillet breeds were made. These adjusted means differ little from the unadjusted means and do not considerably alter the results. That is, differences between years were not due, to any appreciable extent, to differences in the dams. In all cases but one the differences between years were highly significant ($p<0.01$), and in the one exception—length of fleece in the Rambouillets—the difference was significant ($p<0.05$).

TABLE 1.—*Average body weights, fleece weights, and fleece lengths, by years, of Columbia, Corriedale, and Rambouillet female offspring approximately 14 months of age*

Year	Female offspring			Body weight				
	Columbia	Corriedale	Rambouillet	Columbia	Corriedale		Rambouillet	
				Mean	Mean	Adjusted mean [1]	Mean	Adjusted mean [1]
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1925	37	51	33	98.38	83.41	83.23	86.45	85.81
1926	51	51	46	88.14	72.43	72.00	71.20	70.46
1927	60	38	50	98.00	87.39	87.74	87.66	86.74
1928	75	67	89	84.52	73.33	73.24	81.03	81.02
1929	68	51	44	97.68	88.63	88.68	96.73	96.45
1930	91	63	75	96.41	82.46	82.01	93.45	93.11
1931	61	55	68	93.05	76.18	76.08	82,47	82.01
1932	72	58	33	91.69	81.24	81.23	89.24	88.96
1933	68	53	51	99.85	80.60	80.99	88.20	88.00
1934	68	50	27	96.24	81.96	81.88	87.56	87.06
1935	54	59	54	99.11	83.81	84.11	89.80	89.79
1936	57	53	68	106.91	98.26	98.87	93.31	92.67
F ratio [2]				17.85	30.41	31.25	35.07	32.27

TABLE 1.—*Average body weights, fleece weights, and fleece lengths, by years, of Columbia, Corriedale, and Rambouillet female offspring approximately 14 months of age*—Continued

Year	Fleece weight					Length of fleece				
	Columbia	Corriedale		Rambouillet		Columbia	Corriedale		Rambouillet	
	Mean	Mean	Adjusted mean [1]	Mean	Adjusted mean [1]	Mean	Mean	Adjusted mean [1]	Mean	Adjusted mean [1]
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1925	12.30	10.93	10.92	11.98	11.48	3.78	4.01	4.01	2.53	2.51
1926	11.46	10.66	10.51	11.12	11.15	3.71	4.00	3.99	2.63	2.63
1927	12.78	11.64	11.84	12.97	12.84	3.86	4.16	4.19	2.65	2.62
1928	12.04	11.19	11.07	12.05	12.05	3.83	4.02	4.01	2.66	2.65
1929	11.59	11.14	11.04	11.30	11.36	3.80	4.17	4.17	2.59	2.59
1930	13.32	12.75	12.77	12.60	12.56	3.86	4.39	4.40	2.63	2.63
1931	9.40	9.19	9.15	9.33	9.26	3.65	4.02	4.01	2.62	2.62
1932	11.90	11.45	11.58	11.01	11.14	3.89	4.44	4.48	2.72	2.76
1933	12.94	12.30	12.37	13.12	13.15	3.91	4.33	4.33	2.77	2.77
1934	15.27	14.37	14.33	15.79	16.01	3.57	4.10	4.08	2.79	2.82
1935	12.31	10.45	10.46	11.82	11.82	3.81	3.94	3.95	2.62	2.62
1936	12.36	10.93	11.00	11.10	11.17	3.56	3.65	3.64	2.56	2.58
F ratio [2]	43.68	33.59	36.21	36.02	36.60	4.13	13.67	14.12	3.64	2.18

[1] Differences due to dams were eliminated by means of a covariance analysis.
[2] To be significant ($p<0.05$), *F* ratio must be at least 1.81; to be highly significant ($p<0.01$), *F* ratio must be at least 2.27.

The distribution of body weights, fleece weights, and fleece lengths around the yearly means are given in figures 1, 2, and 3, respectively. These figures show the wide variation in each character in each breed in the different years and the absence of consistent trends from year to year. A definite tendency for all breeds to respond to the same in each year is evident.

That there were large variations in the mean yearling body weights, fleece weights, and fleece lengths of the ewes during the 12 years (1925–36) is shown both in table 1 and in figures 1 to 3. These variations appeared to be caused by either differences in sires or the change in environmental conditions from year to year, or by both. When the means of the female offspring of each ram are plotted, as illustrated in figure 4 for the Corriedale breed, it is apparent that there are definite effects of the year of the experiment. The records of the performance of the individual rams are rather parallel, for the most part, especially considering the small number of offspring in many of the years. Of the 17 Corriedale rams used in the study, only 11 had 10 or more female offspring on which data were available in each of 2 or more years. Consequently, only these 11 rams were included in the figure. Figure 4 also shows that in many cases the differences between years are much greater than differences between rams within a year, a fact which suggests that if comparisons of rams are made when offspring are born in different years, adjustments for yearly differences are necessary.

Since, for each ram, data were obtained for only a few years, in analyzing the difference between years (table 1) ram differences were ignored. This practice erred on the conservative side, however, for the within-mean square or error would be reduced if the portion of variance due to the ram differences within each year were taken out.

The data presented indicate clearly the need for consideration of the environmental effects in different years in the progeny testing of rams.

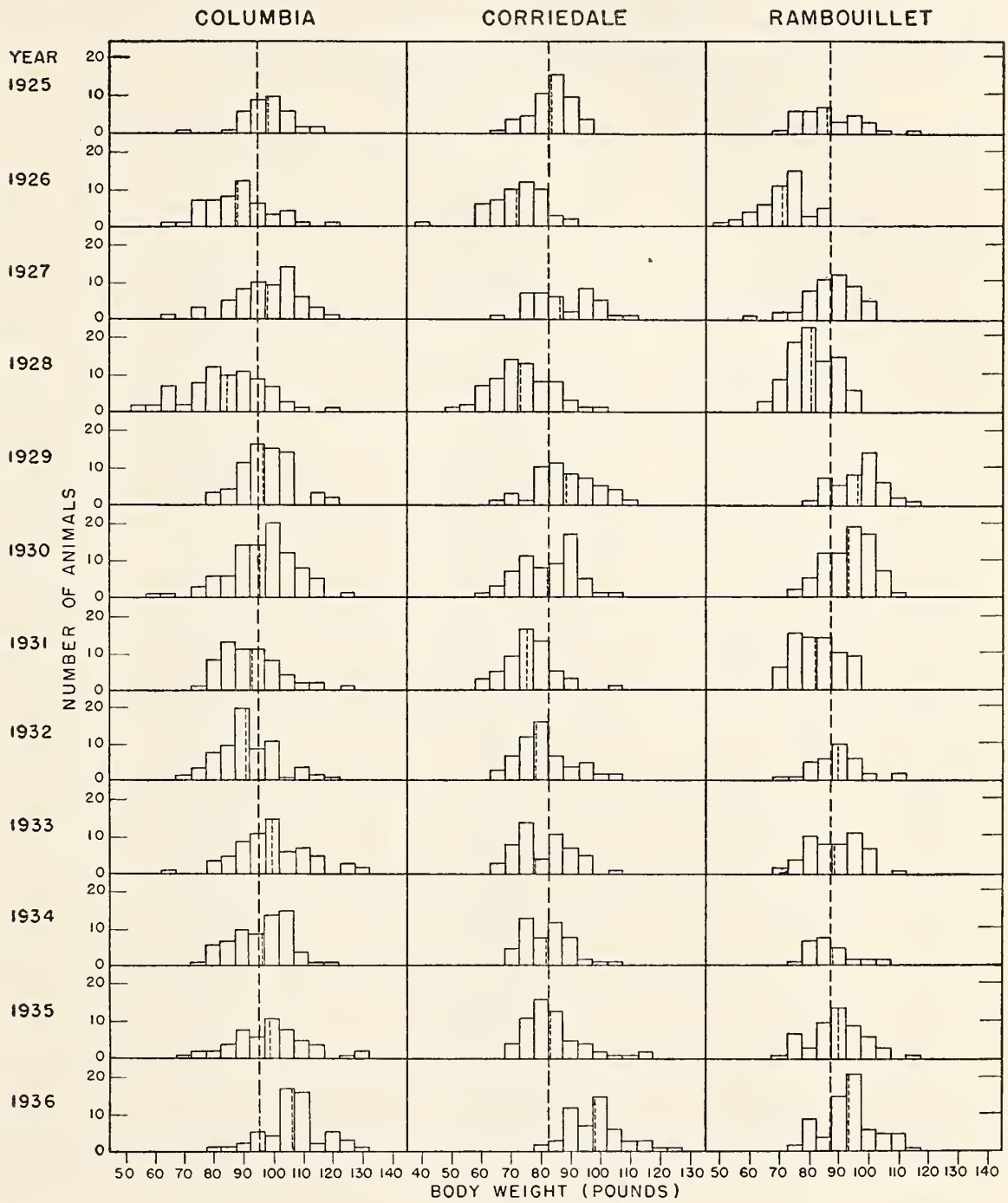

FIGURE 1.—Distributions of body weights of the female offspring in each breed by years. The short dotted lines show the means for each year; the dotted lines continuous from top to bottom show the means for the entire population.

POPULATION STATISTICS FOR BODY WEIGHT, FLEECE WEIGHT, AND FLEECE LENGTH

Data on the means and variability of a sheep population, based on a sample sufficiently large to be fairly representative of that population, are of considerable value both to the experimenter and to the breeder. Such information may be used in several ways in connection with the progeny testing of rams. It may serve as a base to determine whether the mean of the character under consideration in

the current year varies from the mean of past years. It may also be used to determine whether the results obtained on the progeny of any given sire are above or below the average for the population, and the means for any animal may be compared with the population means in the same manner. Data of this type may also be used as a base from which to measure trends in the population.

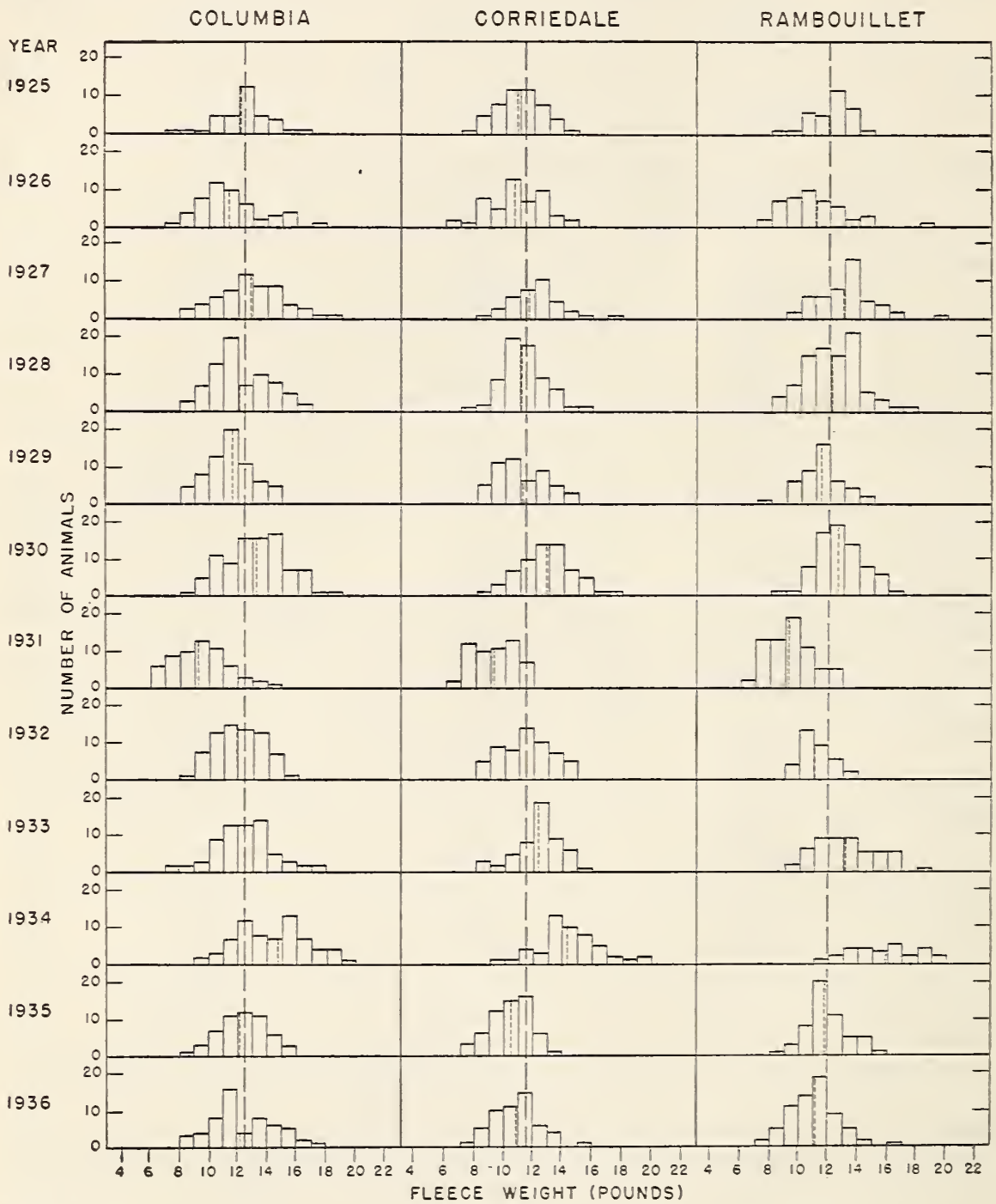

FIGURE 2.—Distributions of fleece weights of the female offspring in each breed by years. The short dotted lines show the means for each year; the dotted lines continuous from top to bottom show the means for the entire population.

Table 2 presents the means and standard deviations of the populations used in this study. These standard deviations are based on the variances remaining after yearly differences were removed. Table 3 is given as an example of the calculations used in obtaining the data shown in table 2.

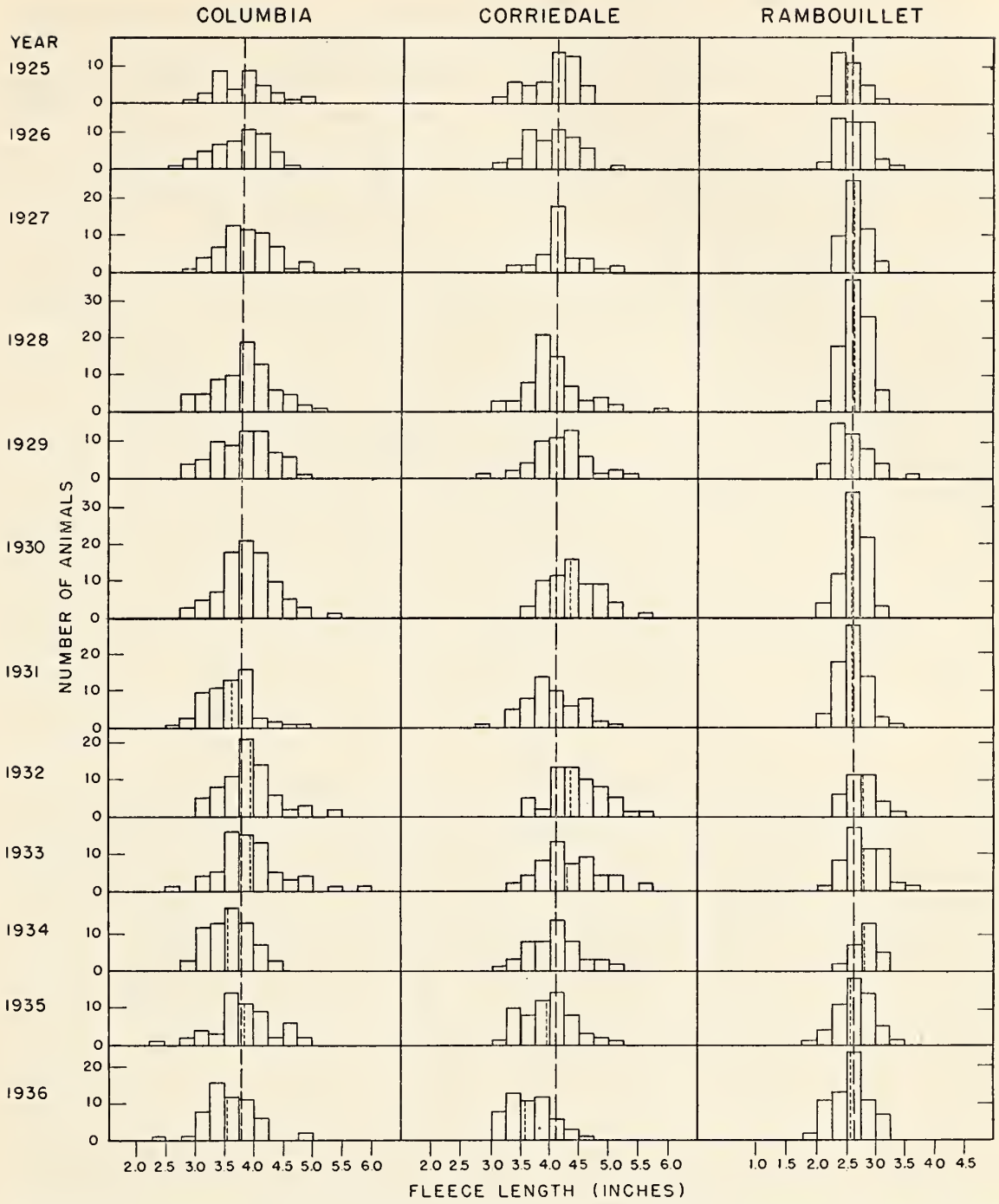

FIGURE 3.—Distributions of fleece lengths of the female offspring in each breed by years. The short dotted lines show the means for each year; the dotted lines continuous from top to bottom show the means for the entire population.

TABLE 2.—*Mean body weights, fleece weights, and fleece lengths of Columbia, Corriedale, and Rambouillet yearling ewes, with the standard deviations based on the variation within years*

Breed	Ewes studied	Body weight		Fleece weight		Fleece length	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*
Columbia	762	95.6	11.00	12.4	1.70	3.8	0.47
Corriedale	709	82.5	9.38	11.4	1.66	4.1	.44
Rambouillet	764	87.4	8.34	11.9	1.74	2.6	.26

TABLE 3.—*Analysis of variance of body weight of Corriedale yearling ewes*

Source of variance	Degrees of freedom	Sum of squares	Mean square	Standard deviation
Between means of years	11	22, 545. 56	2, 049. 50	
Within years	697	61, 301. 15	87. 95	9. 38
Total	708	83, 846. 71		

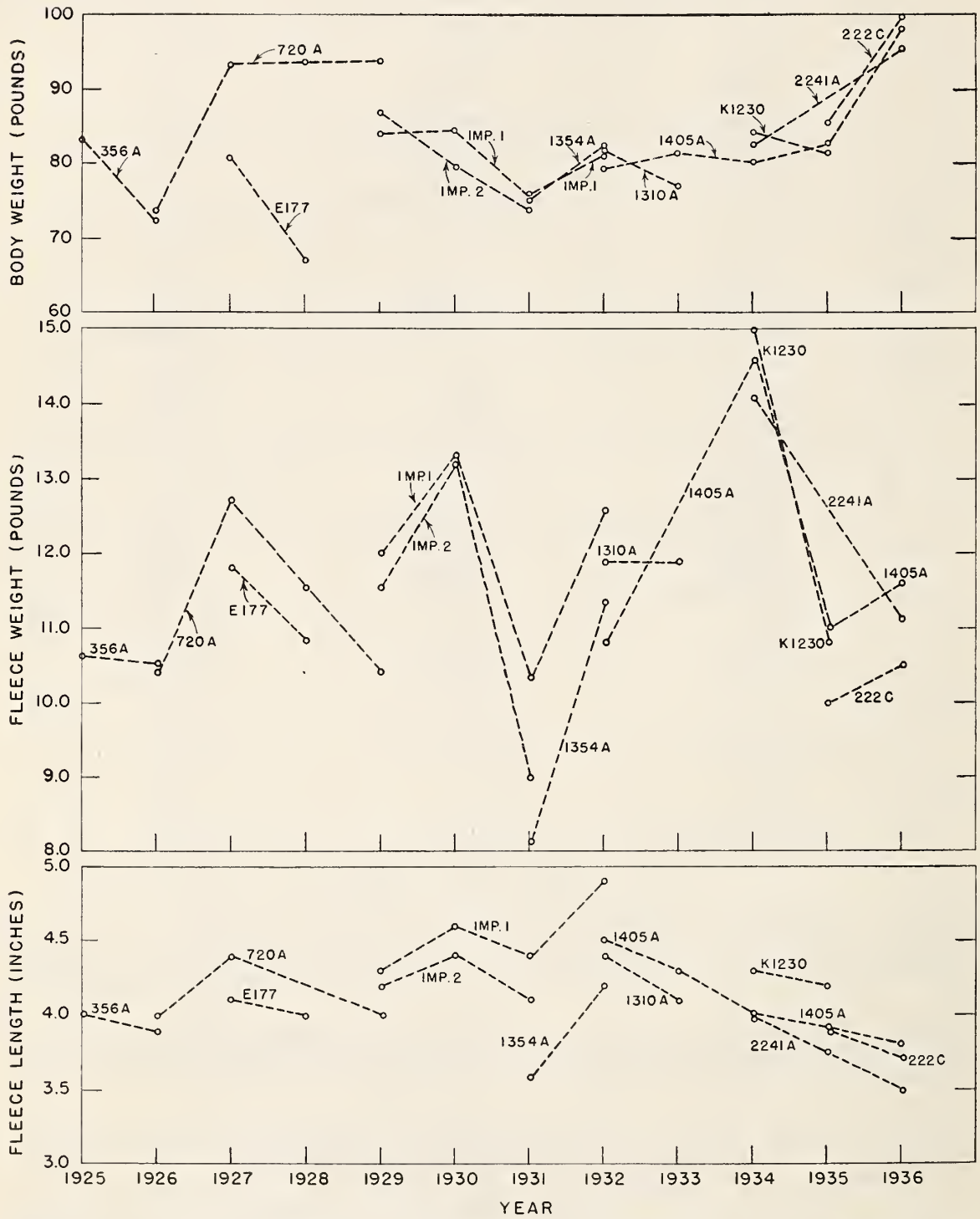

FIGURE 4.—Yearly variations of the female offspring of individual rams in the Corriedale breed for body and fleece weights and for fleece length. Circles indicate the means for the offspring of each ram in each year in which offspring were available.

Since the variance contributed by yearly differences was always significant, the proper standard deviation to use is the one based on the within-mean square. A graphical presentation of the population distributions is made in figure 5. In these histograms yearly differences between progeny have been removed by the empirical method of shifting the means of all yearling data to correspond with the general mean. The numbers of Corriedale and Rambouillet yearling ewes included in table 2 and figure 5 are somewhat greater than the numbers included in table 1 and in figures 1 to 3, since some ewes that appeared as dams but not as offspring were included. These or similar data may be arranged in graphic form such as is shown in figure 5. For example, the body and fleece weight and fleece length of the offspring of several rams used within a year may be plotted on the same scale as the population distribution. The rams may be compared with one another, or the total group compared with the offspring of previous years. If groups are compared directly with the population average used as a standard, care must be taken that proper corrections are made for environmental and other effects.

RELATION BETWEEN DAMS AND DAUGHTERS IN BODY WEIGHT, FLEECE WEIGHT, AND FLEECE LENGTH

In the progeny testing of rams, the relationship between dams and daughters in any character under consideration is important in that it may show the effect of heredity of the dams on the particular character. In the animals used in this study there was no knowledge of the heredity of the dams, and no attempt had been made to breed rams to dams that were comparable in all respects. Therefore, some of the differences in the progeny might have been due to differences between groups of dams. If in the measurement of these characters there is a regression of daughters on their dams, it would be necessary to compare the progeny of rams when the results for the characters studied are adjusted to a common dam basis in order to get the best possible measure of ram differences.

The relationships between dams and daughters were determined by calculation of coefficients of correlation and regression. The methods are adequately described by Fisher (*2*) and Snedecor (*9*). The consistent positive nature of the correlations and regressions obtained (table 4) indicate a relationship that is worthy of consideration. This table shows the average dam-daughter correlations and regressions within the Corriedale and Rambouillet ram groups by years. The values of the correlation coefficients, which are positive with only one exception, range from −0.04 to +0.51, and about one-half are significant. These correlations indicate that they constitute a partial measure of the genotype for the three characters in question. If these phenotypic measures were not related to the genotype, the correlations would vary around 0. The correlation coefficients are of about the same numerical value as the regression coefficients, which fact indicates that the variation observed in the daughters is about the same as that in the dams.

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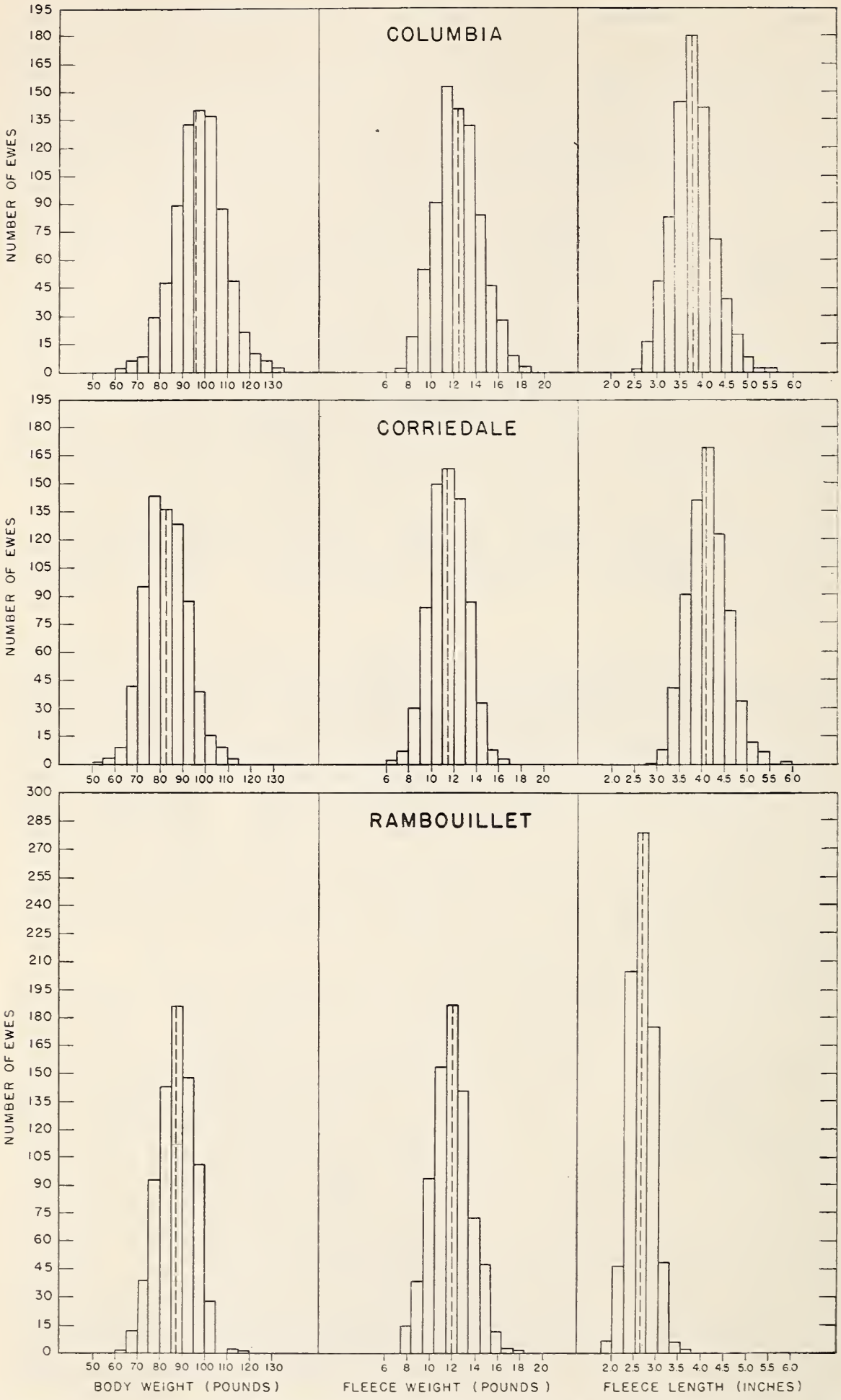

FIGURE 5.—Distributions of body weight, fleece weight, and fleece length of 762 Columbia, 709 Corriedale, and 764 Rambouillet yearling ewes, after adjusting for yearly differences.

TABLE 4.—*Relation between dams and daughters in body weight, fleece weight, and fleece length, as indicated by coefficients of correlation and regression*[1]

Year	Dam-daughter pairs		Body weight				Fleece weight				Fleece length			
			Corriedale		Rambouillet		Corriedale		Rambouillet		Corriedale		Rambouillet	
	Corriedale	Rambouillet	Coefficients of correlation	Regression coefficients	Coefficients of correlation	Regression coefficients	Coefficients of correlation	Regression coefficients	Coefficients of correlation	Regression coefficients	Coefficients of correlation	Regression coefficients	Coefficients of correlation	Regression coefficients
	Number	*Number*												
1925	51	33	−0.04	−0.03	0.35*	0.28*	0.19	0.19	0.19	0.16	0.27*	0.22*	0.50**	0.39**
1926	51	46	.15	.17	.29*	.40*	.06	.10	.25	.40	.40**	.32**	.07	.07
1927	38	50	.26	.32	.28*	.38*	.51**	.43**	.29*	.38*	.35*	.26*	.39**	.28**
1928	67	89	.08	.10	.24*	.26*	.03	.04	.01	.01	.34**	.44**	.19	.20
1929	51	44	.29*	.37*	.23	.22	.48**	.49**	.20	.21	.20	.20	.19	.29
1930	63	75	.24	.19	.01	.01	.25*	.31*	.12	.13	.13	.13	.11	.09
1931	55	68	.39**	.34**	.24	.25	.33*	.23*	.04	.03	.30*	.21*	.33**	.41**
1932	58	33	.34**	.48**	.30	.34	.37**	.37**	.10	.06	.37**	.31**	.20	.25
1933	53	51	.42**	.45**	.13	.15	.49**	.54**	.40**	.49**	.40**	.35**	.30*	.33*
1934	50	27	.14	.15	.42*	.62*	.23	.45	.11	.19	.27	.30	.15	.11
1935	59	54	.18	.24	.30*	.35*	.25*	.22*	.34*	.27*	.44**	.43**	.02	.01
1936	53	68	.41**	.46**	.09	.11	.41**	.41**	.14	.15	.36**	.42**	.33**	.31**

[1] Single asterisk indicates a significant coefficient ($p<0.05$); double asterisk, a highly significant coefficient ($p<0.01$).

The fact that the correlations tended to be generally positive may be considered as evidence that the heredity of the dams accounts for some of the variation in the daughters. That this factor accounts for only a small part of the variation in most cases is shown by the generally low correlations (table 4). This relationship seems to be of sufficient importance, however, for it to be considered in selecting ewes on which to test rams.

DIFFERENCES BETWEEN PROGENY OF RAMS IN BODY WEIGHT, FLEECE WEIGHT, AND FLEECE LENGTH

The rams used in this study were to some extent proved rams, because they were rams from which at least 20 female offspring had been retained until yearling data were taken. Therefore, the poorer rams from which fewer or no offspring were retained to 1 year of age had been eliminated. If all the rams used, whether producing good or poor offspring, could have been represented in the study by all their offspring, the chances of demonstrating differences in the progeny of rams would undoubtedly have been greater.

Table 5 presents the mean body weights, fleece weights, and fleece lengths, by years, of the female offspring of each ram, having progeny born in the same year, in the Corriedale and Rambouillet breeds. Since, as already stated, no attempt was made to breed rams to similar ewe groups having equal means and variances for the characters studied, it was possible that differences in the progeny were influenced to some extent by the ewes. Therefore, the progeny means were adjusted to a common-dam level by the analysis of covariance described by Snedecor (*9*). This adjustment was made on the average regression of daughters on dams within the ram groups, it being assumed that the regressions for each group belong to a common population. It is possible to test the significance of the difference

between the individual regressions, but it would not be expected that the heredity of one group of ewes would have a greater effect on the daughters than another group under similar conditions. Such an analysis was made in the Corriedale and Rambouillet breeds for each character in each year. Table 6 gives the analysis for body weight of Rambouillet female progeny for 1925 and is included to show the type of analysis used in arriving at the results presented in table 7. In this particular case the differences between dams were small, and significant ram differences would have been found even if the adjustments for differences in dams had not been made, although this would not always have been the case.

TABLE 5.—*Mean body weights, fleece weights, and fleece lengths of female offspring of Corriedale and Rambouillet rams*

CORRIEDALE

Year	Ram designation	Offspring	Body weight	Fleece weight	Fleece length	Year	Ram designation	Offspring	Body weight	Fleece weight	Fleece length
		Number	*Pounds*	*Pounds*	*Inches*			*Number*	*Pounds*	*Pounds*	*Inches*
1925	K221	8	84.0	12.1	4.0	1931	Imp.1	10	75.5	10.3	4.4
	356A	11	83.1	10.6	4.0		Imp.2	14	73.5	9.0	4.1
	K160	32	83.4	10.7	4.0		1405A	5	72.4	9.2	3.8
1926	K221	11	71.5	11.6	4.2		1310A	9	77.8	9.7	4.1
	356A	18	72.2	10.5	3.9		1354A	13	75.0	8.1	3.6
	K160	4	70.2	10.8	3.9		1673A	4	92.3	9.5	4.1
	720A	14	73.6	10.4	4.0	1932	Imp.1	10	81.2	12.6	4.9
	870A	4	74.5	9.6	3.8		1405A	10	79.2	10.8	4.5
1927	K221	2	86.0	11.5	4.0		1310A	13	81.6	11.9	4.4
	720A	18	93.3	12.7	4.4		1354A	17	82.0	11.3	4.2
	E177	12	80.8	11.8	4.1		1673A	4	77.3	9.6	4.3
	K401	6	83.3	10.6	3.8		K1230	4	86.0	11.3	4.4
1928	870A	21	74.7	10.9	4.0	1933	1405A	17	81.2	12.7	4.3
	E177	17	66.7	10.8	4.0		1310A	16	76.6	11.9	4.1
	K401	25	75.8	11.6	4.1		1673A	20	83.2	12.3	4.6
	953A	4	79.2	12.0	4.8	1934	1405A	18	80.1	14.6	4.0
1929	720A	16	93.8	10.4	4.0		K1230	15	84.1	15.0	4.3
	953A	5	89.8	10.5	4.4		1673A	6	81.7	12.6	4.1
	Imp.1	12	83.8	12.0	4.3		2241A	11	82.4	14.1	4.0
	Imp.2	18	86.0	11.5	4.2	1935	1405A	19	82.5	11.0	3.9
1930	953A	23	82.6	12.0	4.4		K1230	10	81.5	10.8	4.2
	Imp.1	14	84.4	13.3	4.6		222C	30	85.4	10.0	3.9
	Imp.2	18	79.6	13.2	4.4	1936	1405A	15	98.0	11.6	3.
	1405A	8	85.0	13.0	4.0		2241A	12	95.5	11.1	3.6
							222C	26	99.7	10.5	3.5

RAMBOUILLET

1925	P93	5	101.6	13.1	2.7	1931	823R	21	86.1	9.3	2.6
	3149	11	81.8	11.9	2.5		1714R	9	79.4	9.7	2.6
	9179	17	85.0	11.7	2.5		1802R	25	81.2	8.9	2.6
1926	P93	7	69.9	9.4	2.7		1851R	13	81.2	9.8	2.8
	3149	12	68.1	11.7	2.7	1932	1469R	10	91.5	10.6	2.7
	9179	17	73.1	11.6	2.6		1714R	4	90.2	11.4	2.8
	59R	10	72.7	9.8	2.5		1802R	9	91.8	11.2	2.8
1927	P93	5	81.8	14.7	2.8		1851R	6	83.0	10.5	2.7
	3149	12	85.0	13.8	2.6		2046R	4	86.2	11.9	2.4
	59R	16	87.0	12.7	2.7	1933	1714R	9	81.7	13.7	2.8
	823R	17	91.9	12.1	2.6		1851R	15	86.9	13.8	3.0
1928	P93	23	81.7	12.7	2.7		2046R	8	93.6	14.4	2.7
	59R	21	77.7	11.8	2.7		2220R	14	90.4	11.5	2.5
	823R	21	82.0	11.3	2.5		2589R	5	89.0	12.6	2.7
	505R	15	80.8	12.1	2.7	1934	2220R	14	87.4	16.4	2.7
	818R	5	83.4	11.4	2.6		2314R	6	88.8	15.8	2.9
	1254R	4	87.2	14.4	2.8		2589R	7	86.9	14.5	2.8
1929	59R	10	90.5	11.7	2.7	1935	2046R	11	88.4	12.3	2.6
	823R	9	102.8	11.6	2.7		2220R	15	86.9	10.8	2.3
	505R	9	98.9	12.1	2.6		2314R	17	94.5	12.8	2.8
	818R	8	93.5	10.2	2.5		2951R	11	88.0	11.3	2.7
	1254R	4	94.0	10.0	2.3	1936	2220R	20	93.7	10.5	2.3
	1469R	4	103.0	11.2	2.6		2314R	16	95.7	11.4	2.6
1930	823R	20	94.8	12.6	2.6		2589R	15	93.6	12.0	2.7
	818R	7	97.6	12.9	2.6		2951R	17	90.4	10.7	2.7
	1254R	18	92.7	12.8	2.7						
	1469R	8	95.2	12.8	2.9						
	1714R	3	88.3	13.2	2.7						
	1802R	7	95.6	12.1	2.5						
	1851R	12	88.8	12.2	2.6						

TABLE 6.—*Analysis of covariance and test of significance of adjusted ram means based on weights of female progeny of Rambouillet rams in 1925*

Source of variance	Degrees of freedom	Sums of squares and products			Errors of estimate		
		Sx [1] [2]	*Sxy*	*Sy* [2]	Sum of squares	Degrees of freedom	Mean square
Between means of progeny of rams	2	26.97	177.67	1,419.35			
Within group	30	2,445.27	694.6	1,610.84	1,413.53	29	48.74
Total	32	2,472.24	872.27	3,030.19	2,722.42	31	
For test of significance of adjusted means					1,308.89	2	[2] 654.45

[1] x=measurements of dams, y=measurements of daughters.
[2] F ratio=13.4; to be highly significant ($p<0.01$), F ratio must be at least 5.4.

Table 7 summarizes the significance of results in these analyses for all the years and characters studied. Significant or highly significant ram differences were detected in only 20 of 72 comparisons, 10 of these being observed in each breed. No attempt was made to obtain differences among rams for offspring born in different years or to obtain the ram-year interactions. The present results are of value because they indicate that even in the selected population for which data are available, differences among rams were demonstrated in a portion of the years. Therefore, the chances of finding differences among untried rams, where each ram is mated to a similar and adequate number of ewes, should be very good.

TABLE 7.—*Significance of difference of adjusted means of body weight, fleece weight, and fleece length of female offspring of Corriedale and Rambouillet rams* [1]

Year	Body weight		Fleece weight		Fleece length	
	Corriedale	Rambouillet	Corriedale	Rambouillet	Corriedale	Rambouillet
1925	−	++	−	−	−	−
1926	−	−	−	+	−	−
1927	++	−	−	−	++	−
1928	+	−	−	+	−	−
1929	+	++	−	−	−	−
1930	−	−	−	−	−	−
1931	−	−	−	−	++	−
1932	−	−	++	−	++	−
1933	−	+	−	++	+	+
1934	−	−	−	−	−	−
1935	−	−	++	++	−	++
1936	−	−	++	−	−	++

[1] Key: ++, highly significant ($p<0.01$); +, significant ($p<0.05$); −, not significant.

In case the relationships between dams and daughters are low, or when rams are bred to comparable ewe groups, little is gained by adjusting the results from the progeny for differences in dams. In this case the ram differences could be tested by the usual analysis-of-variance method. In setting up future experiments it would be desirable to compare rams only when bred to ewe groups that have similar means and variability for the character being tested.

APPLICATION OF RESULTS TO THE PROGENY TESTING OF RAMS

Detailed statistical analyses of progeny records are very useful to the experimenter who is attempting to solve the problems involved in progeny testing, but in practical breeding operations they are of little value as they involve an understanding of complex statistical procedures and require much time for the calculation of results. The following is a simple method of comparing rams, which should be both workable and useful.

Assuming that a breeder or experimenter has facilities for testing 15 rams on 20 ewes each in a breeding season, the first step is to divide the ewes into as nearly comparable lots as possible in the characters under consideration. When the resulting progeny reach the age at which data are to be taken, the records are obtained, set up in frequency-distribution tables, and transferred to a graph of the type shown in figure 6. In this figure the distributions of offspring of 3

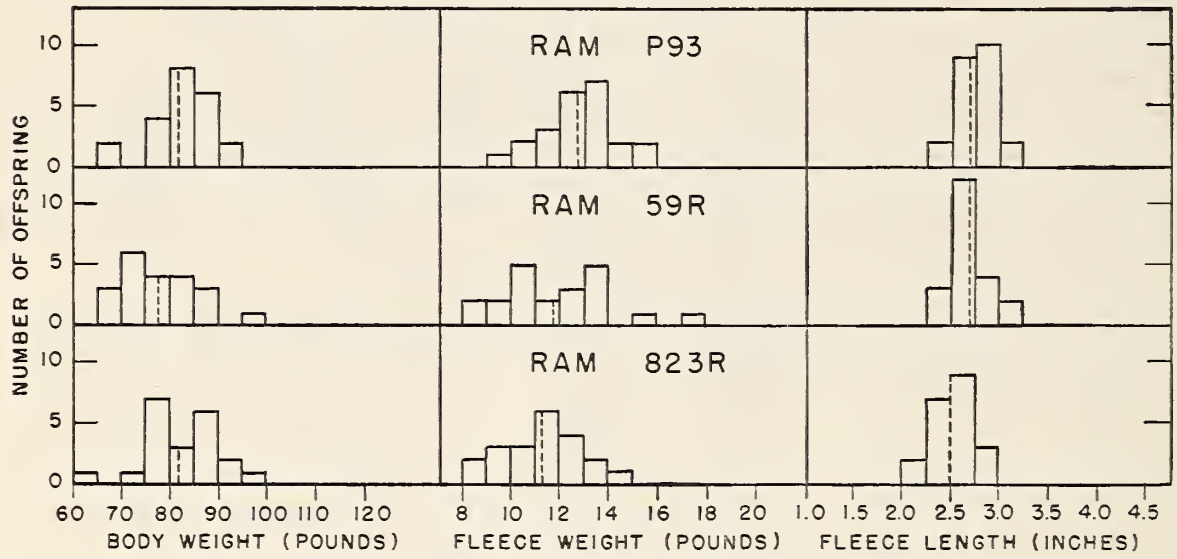

FIGURE 6.—Distributions and means for body weight, fleece weight, and fleece length (taken at 14 months of age) of female offspring, born in 1928, sired by Rambouillet rams P93, 59R, and 823R.

Rambouillet rams for 1928 are shown. The dotted lines indicate the means. If one were selecting a ram from this group, on the basis of the three characters indicated in the figure, first choice would be P93. Figure 6 shows that P93 and 823R have equally heavy offspring, but those of P93 are more uniform in weight. This figure also shows that the offspring of P93 are superior to those of both 59R and 823R in fleece weight and that the offspring of P93 and 59R are equally good in fleece length. Thus P93 would be ranked first in body weight and fleece weight of the offspring and equally as good as the second ram in fleece length of the offspring.

With the use of this method, the equipment and analytical facilities for evaluating rams are kept at a minimum, yet the differences between rams, as indicated by their progeny, can be clearly seen and the rams that produce the most desirable progeny for the desired characters can be selected for use as flock sires. Until practical and more critical methods are evolved for the progeny testing of rams, this

method should be used when possible. It is similar to the one used for evaluating boars in the Danish program of progeny testing.

The problem of making selections is increased with each additional character that is given consideration. In addition to body weight, fleece weight, and fleece length, the breeder may wish to consider such characters as absence of skin folds, mutton form, openness of face, and diameter or fineness of wool fibers. All these characters can be recorded as measures or scores and set up in graphic form as shown in figure 6. The number of compromises that must be made in selecting rams will naturally increase with each increase in the number of characters for which selection is being made. Therefore, it is imperative that the breeder who desires to make rapid progress confine the number of characters on which selections are based to those that are of major importance.

The progeny test may be refined further by allowing for the effects of environmental factors on the characters involved. For example, Phillips and Dawson (*6*, *7*) have shown that such factors as type of birth, time of birth, and birth weight affect subsequent weights to some extent and that the effects of these factors on development are reflected in selection, the lambs having an environmental advantage naturally being favored. Sex also affects the rate of development. If the progeny of one ram had a preponderance of twins or of ewe lambs, the group would be expected to weigh less than one containing more singles and approximately equal numbers of each sex. In such cases, a truer picture of the ram's genotype would be obtained by adjusting for such differences before making comparisons. The basis for making such adjustments are presented by Phillips and Dawson (*7*) for three mutton breeds reared under farm-flock conditions. Similar factors for the wool breeds reared under range conditions would be useful. If the number of ewes to which each ram is mated is sufficiently large, the populations in most cases will be nearly equal in the character in question, and adjustments of this type would not markedly increase the accuracy of the test. In the work reported in this circular, records from female offspring only were used; hence the problem of sex differences was not involved.

The time element also is important. Data used in this study were obtained on yearling ewes. If ram lambs or yearling rams are used in test matings in the fall of one year, with the hope of selecting the outstanding individuals for use the following fall, the offspring must be evaluated on the basis of data taken on the offspring at weaning or shortly thereafter. The time elapsing between the taking of data and the beginning of the next breeding season is short; hence the method of analysis must be rapid. If the offspring are to be evaluated on the basis of yearling data, two breeding seasons must elapse from the time rams are used in test matings until the selected rams can be used in regular breeding work. This phase of the problem is somewhat apart from the one under consideration, but it must always be borne in mind. Further work is needed to determine the earliest age at which satisfactory data may be obtained.

In selecting a sire on the basis of a progeny test, the degree of confidence that one will have in the validity of a selection will depend on several things. Assuming the herd environment and average merit of the dams to be the same for 2 sires, the significance of an observed mean difference becomes greater as the number of offspring increases,

though somewhat in accordance with the law of diminishing returns. As the variance of a population increases, either a greater mean difference between sires or a larger number of individuals is necessary to give the same amount of confidence in a selection. In considering the question of the number of offspring necessary to prove a sire, Lush (*3*) in studying dairy cattle suggested a minimum number of 5. He pointed out (*4, pp. 508–509*), however, that if random environmental effects are important and proper corrections are made for herd environment and merit of dams, the accuracy of the sire rating may be considerably increased by increasing the number of progeny tested. An arbitrary number of 20 ewes was used in the ram-testing procedure suggested in this circular. From this number of ewes at least 15 offspring would be expected for testing purposes, assuming that both male and female offspring were used. Whether this number is adequate or more than adequate to obtain a reasonably accurate measure cannot be determined until further studies are made in regard to the sources of variability of ram offspring.

SUMMARY AND CONCLUSIONS

Data on body weight, fleece weight, and fleece length of 762 Columbia, 709 Corriedale, and 764 Rambouillet yearling ewes, born during the years 1925 to 1936, inclusive, were used in this study. Included in these numbers were offspring of 11 Columbia, 17 Corriedale, and 17 Rambouillet rams. These animals were raised under range conditions at the United States Sheep Experiment Station, Dubois, Idaho. The analysis brought out the following points that are important when planning the progeny testing of rams:

Yearly variations in the characters studied were marked. The variation between years was highly significant in all characters for all breeds, except length of fleece in the Rambouillet, for which the difference between years was significant.

Correlations between dams and daughters within years ranged from −0.04 to +0.51, all correlations but one being positive. This portion of the study was based on 649 dam-daughter pairs in the Corriedale breed and 638 in the Rambouillet breed.

In the animals studied, which consisted of the progeny of rams from which at least 20 female offspring had been retained until yearling data were taken, significant or highly significant differences between rams were found in 20 of the 72 comparisons made. These findings indicate that ram differences can be demonstrated even when progeny are used that have been subjected to limited selection at weaning time.

The findings also indicate the desirability of basing comparisons of rams on progeny reared the same year or, if this is not possible, the need for making adequate adjustments for differences in years. The relationships found between dams and daughters show the desirability of mating all rams being tested to comparable groups of ewes or, if this is not done, the necessity of adjusting data obtained on the offspring for differences due to dams.

Data on all the individuals available are summarized to give a graphic picture of the yearling ewe populations for the three characters studied. These data show the mean and variability in each of the characters in the three breeds and serve as a demonstration of a

means by which comparisons of individuals or rams or yearly populations can be made.

A simple and relatively rapid method is described for comparing the progeny of rams under field conditions.

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